University of Florida
Department of Mechanical and Aerospace Engineering
Crankshaft Journal Bearing Design
Course EML3005

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ABSTRACT

The designed of a crankshaft journal bearing for a four-stroke engine diesel was generated by using the correct nominal bearing clearance to persuade a maximum allowance oil temperature raise of 50°F as well as the minimum allowable film-thickness of 80 μ-in. Using the bearing nominal clearance to get the values for Sommerfield number, S, for each of the angles undergoing a counterclockwise rotation of the crank. Moreover, factors like Pmax, ho, and ΔT of the crankshaft journal bearing where found from graphs using the Sommerfield number, S. The parameters were plotted to demonstrate how the angle of the crank has an effect on them.

Furthermore, the locus of the journal center inside the clearance circle was produced. The radial clearance, the journal diameter, and bearing inner diameter were calculated with tolerances. This crankshaft journal bearing design showed the importance of the Sommerfield's number and the factors used like temperature, radial clearance, and others. Also, it helped the group to get familiar with the development of this type of machinery.

INTRODUCTION/OBJECTIVE

The purpose of this project was to precisely design a crankshaft journal bearing for a four-stroke diesel engine. To properly design a crankshaft journal bearing the combustion forces, inertia forces of the connecting rod and crank, and the speed and throttle position must be taken into account. The specifications state that the forces in the crank mechanism for the engine are periodic over a 720-degree crank rotation and the forces experienced are given in 10 degree increments. The nominal bearing clearance can be found by using the given bearing parameters and the maximum resultant load encountered during the cycle. The maximum pressure (P_{max}), minimum film thickness (h_o), change in temperature (ΔT), journal center position (e, Ø), and friction loss were calculated using a combination of Matlab, Excel, and Shigley's Mechanical Engineering Design. Figure 1 and 2 show the slider crank mechanism considered in this project.

APPARATUS

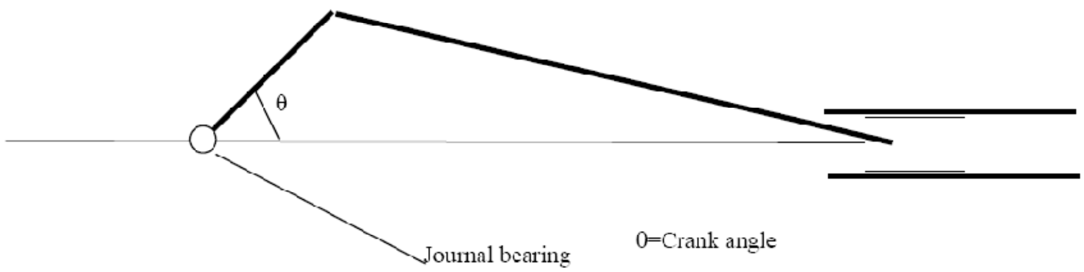


Figure 1. Slider crank mechanism with crank angle

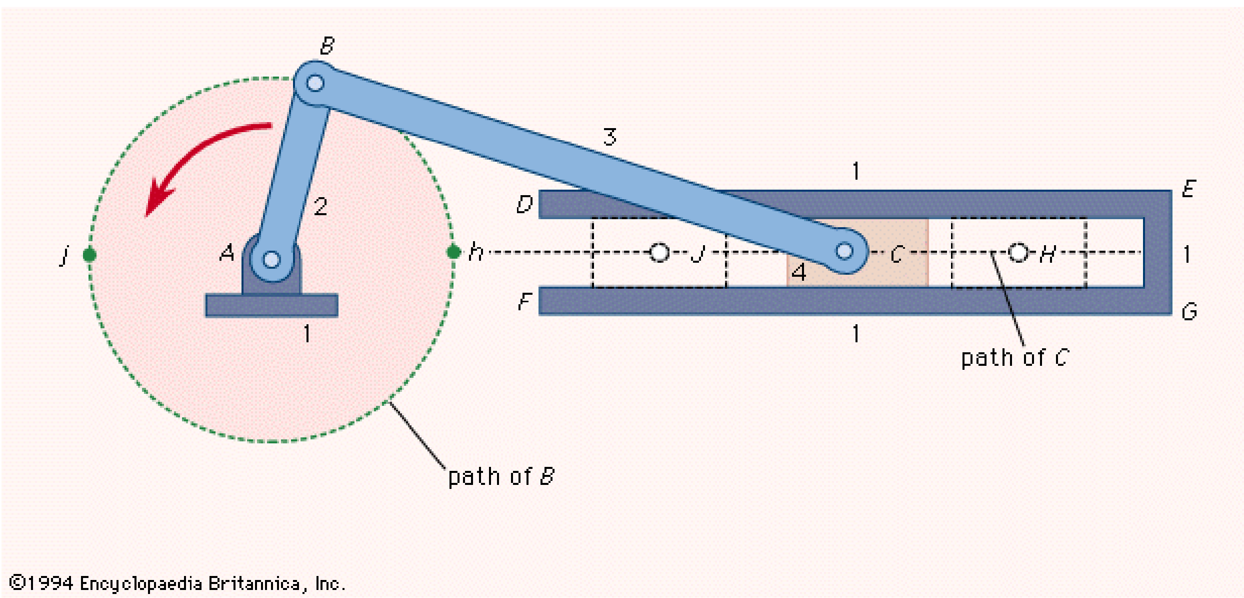


Figure 2. Slider crank mechanism

PROCEDURE

The design process was streamlined by incorporating all the necessary graphs from Shigley's Mechanical Engineering Design into Excel. Curve fits were then produced using either Excel's or Matlab's curve fit software. The equations produced from these curve fits were then used in Excel to calculate results which could be changed easily and quickly. A Matlab program was created to iterate between the average bearing temperature and temperature change using these equations. The Matlab program, equations for the curve fits, and their accompanying graphs are shown in the Appendix.

The clearance range was determined based on the ΔT and h_o restrictions and using the Matlab iterative program. Once a nominal clearance was chosen, graphs of h_o and Pmax were produced for the given crank shaft angles, ϴ. A locus plot of the journal center was also created by converting the polar points (e, Ø) to Cartesian coordinates . The mean viscous friction loss was calculated by averaging the friction at every point during the 720 degrees of rotation. Tolerances were chosen based off typical tolerances for journal bearings and design region consideration.

RESULTS AND DISCUSSION

The first task of the project was to determine the possible design region within the constraints given. The specifications stated that the temperature change within the bearing could not be greater than 50 degrees Fareinheit nor could the minimum film thickness be less than 80 micro-inches. Plotting the results using Matlab and applying the constraints, the design region was produced as shown in Figure 3.

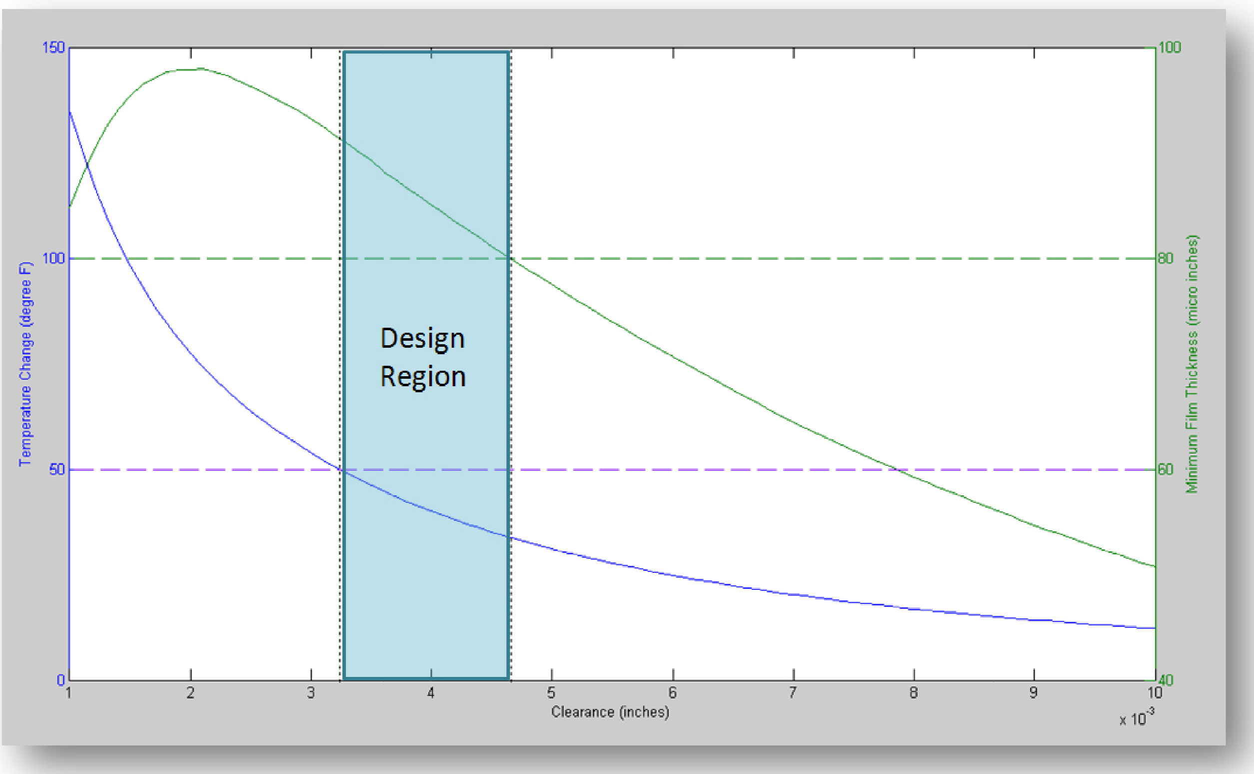


Figure 3. ΔT & h_o vs. Radial Clearance

Noting that typical tolerances for journal bearings of this type are approximately ±0.0004 inches and taking note of the our design region of 0.0013 a nominal clearance of 0.0039 was chosen. This would allow for wear and tear as well as provide an additional safety factor.

The minimum film thickness was calculated using the nominal clearance and is shown in Figure 4. The smallest minimum film thickness occurs at $\Theta = 10°$ which is the maximum force encountered. The maximum resultant force causes the journal bearing to come closest to the wall during this instant. The film thickness is the highest at $\Theta = 700°$ because it is when the minimum resultant load occurs. This follows the same logic as above.

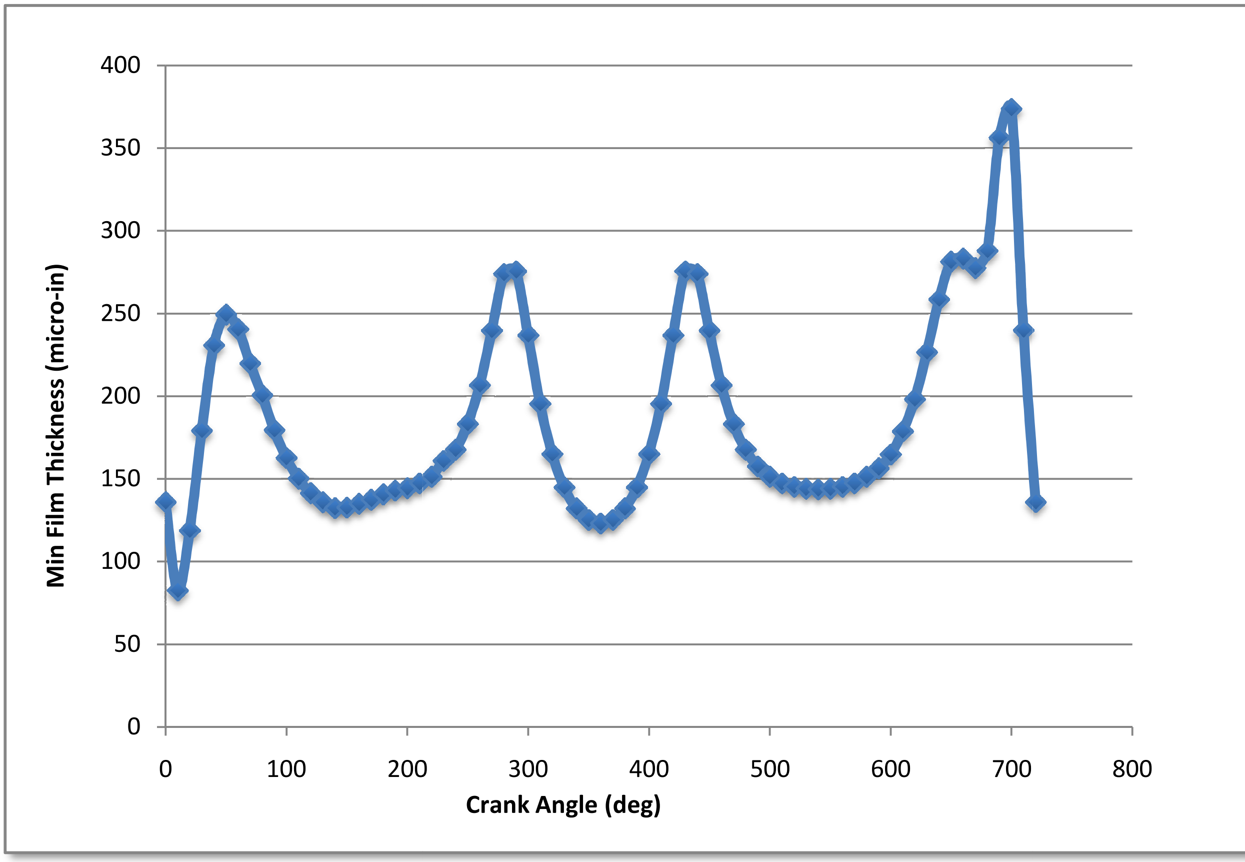


Figure 4. h_o vs. Crank Angle

Figure 5 seems to be inversely proportional to Figure 4 having a maximum at $\Theta = 10°$ and a minimum at $\Theta = 700°$. The highest P_{max} is found where the resultant load is the highest, because at this point the journal and the bearing are forced to be closer together as stated above. The same applies for the lowest P_{max}. It can be assumed that the P_{max} is proportional to the resultant load. The maximum P_{max} is important since it dictates the design and material of the bearing. The higher the pressure, the stronger the journal bearing must be.

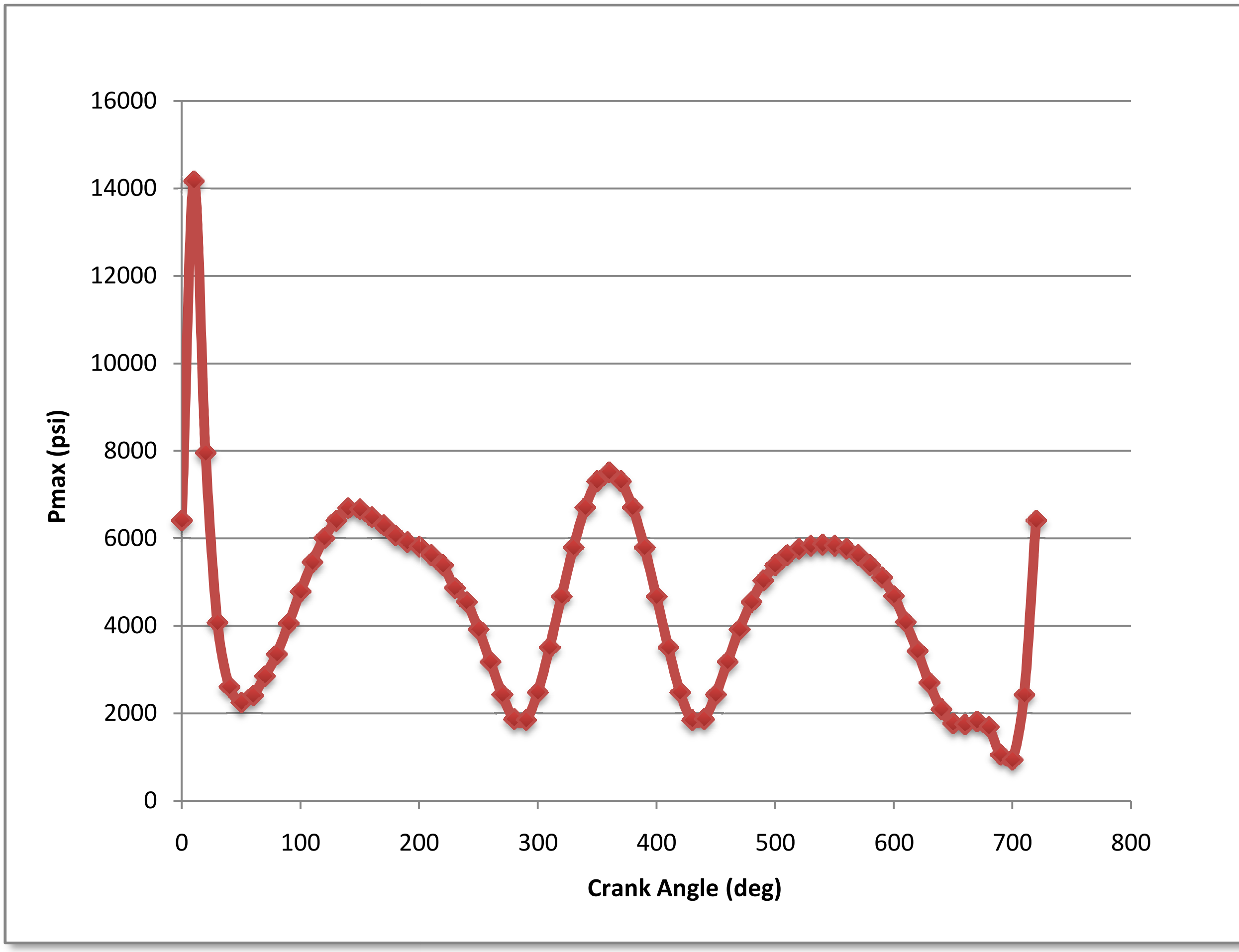


Figure 5. P_{max} vs. Crank Angle

Figure 6 shows the locus of the journal inside the clearance circle during two counterclockwise revolutions. The data was normalized with respect to clearance to improve the chart readability. As can be seen from the graph, the journal bearing is close to the outside wall during the entire duration of the 720 degree revolution.

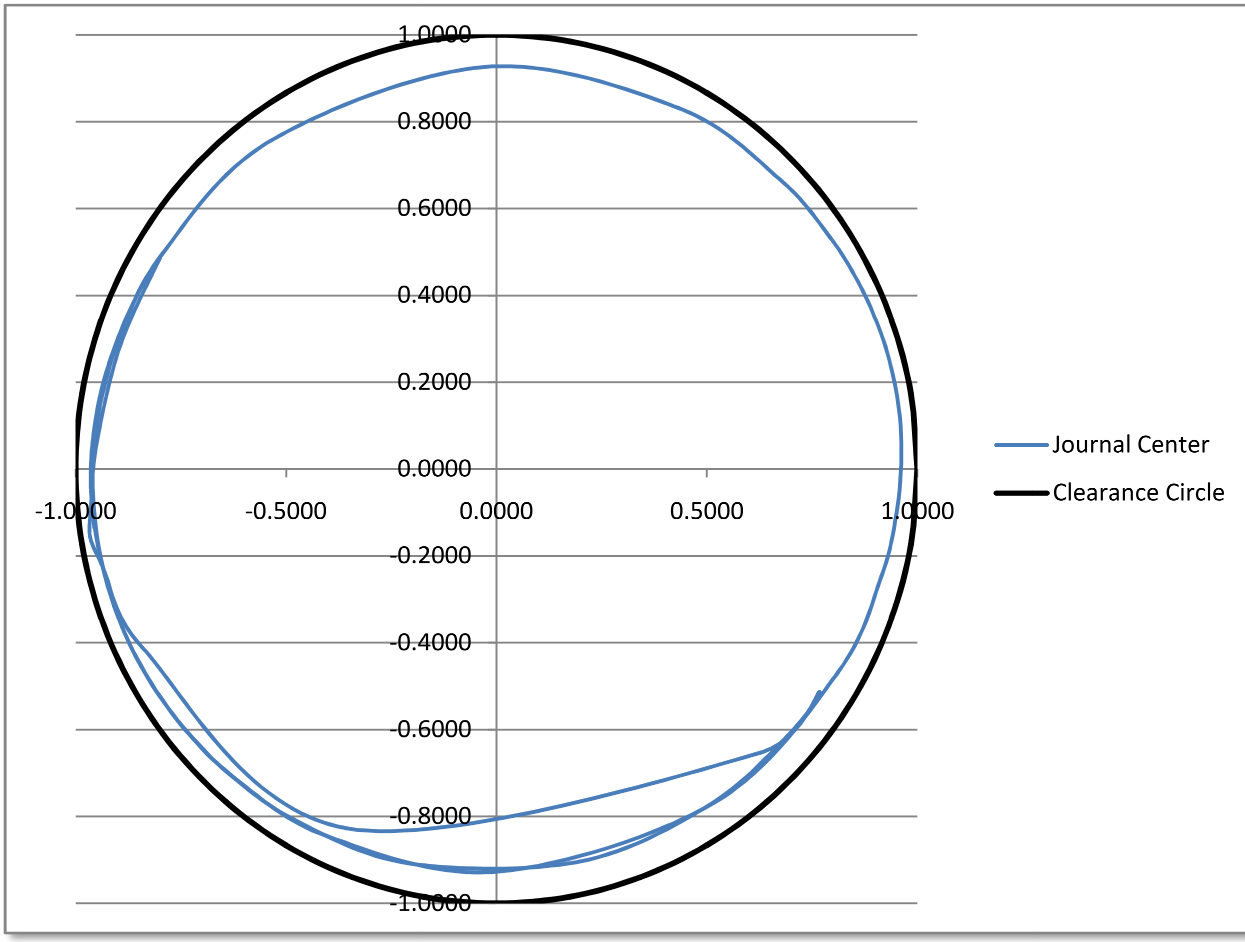


Figure 6. Locus of the journal center inside the clearance circle (normalized with respect to clearance)

The frictional loss in horsepower is shown in Figure 7. These values were averaged to obtain a mean viscous friction loss of 0.265 HP. It was determined that altering the clearance within the design region would produce a negligible effect on the HP loss. Therefore, the clearance originally chosen was not changed.

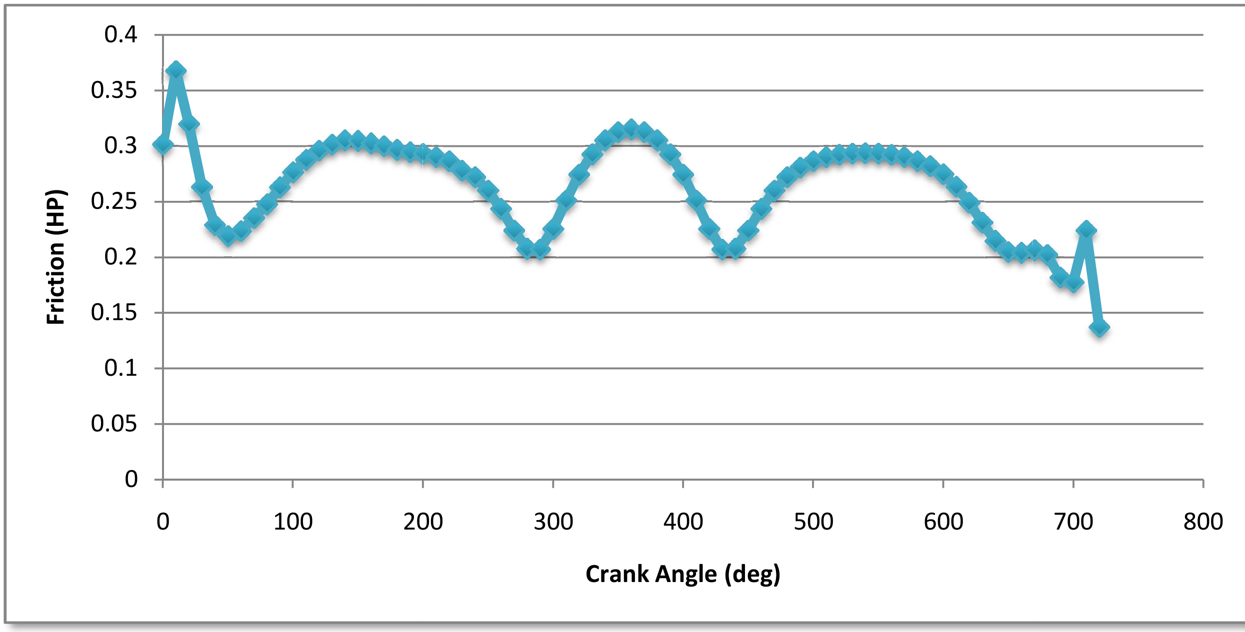


Figure 7. Friction loss in units of HP.

The final parameters of the bearing, including tolerances, are shown in Table 1. The maximum oil temperature change was calculated based off of the minimum possible journal diameter and the maximum possible bearing diameter (minimum clearance possible).

Table 1. Final Parameters of Bearing Design.

Bearing Length	2 in
l/d	0.25
SAE 20 oil with inlet temp	125 F
Journal Speed	5 rev/sec
Minimum Allowable h_o	80 μ-in
Max allowable oil temp rise	50 F
Journal Diameter	8.0000 ± 0.0002 in
Bearing Radial Clearance	0.0039 ± 0.0004 in
Bearing Inner Diameter	7.9961 ± 0.0004 in
Mean Viscous Friction Loss	0.265 HP
Maximum Oil ΔT	48.97 F

Conclusion

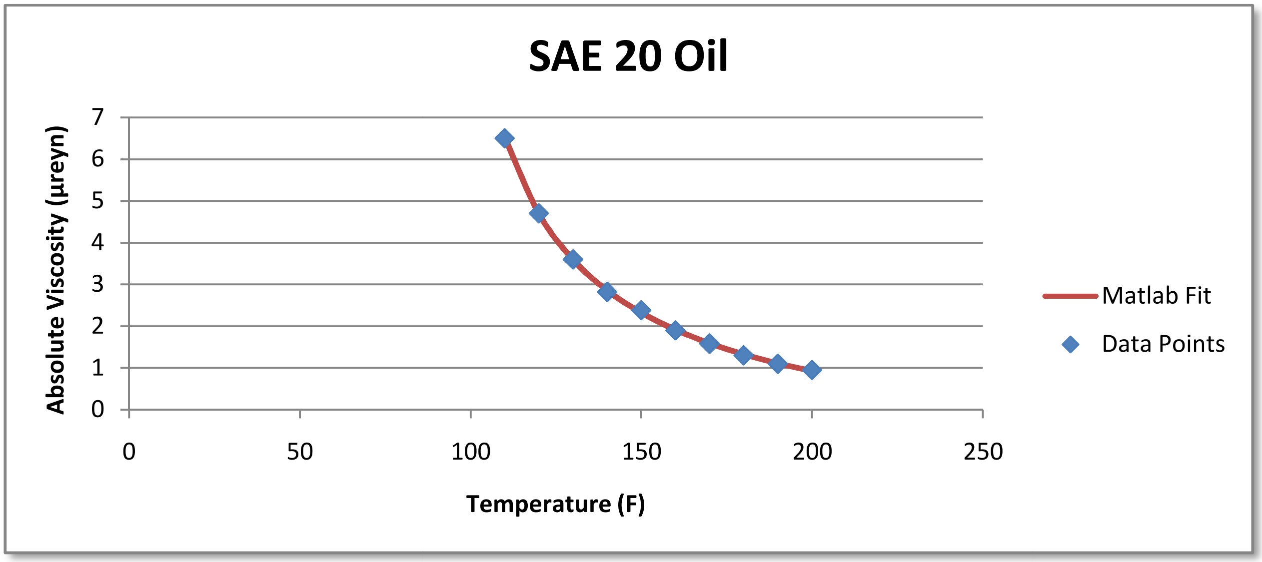
The margin initially decided on was beneficial due to the tolerances and the resulting temperature change for the minimum clearance. In addition, the bearing will still perform up to the specifications after wear and tear increases the clearance. Therefore, the bearing will perform as needed for the conditions specified for an extended range of cycles.

References

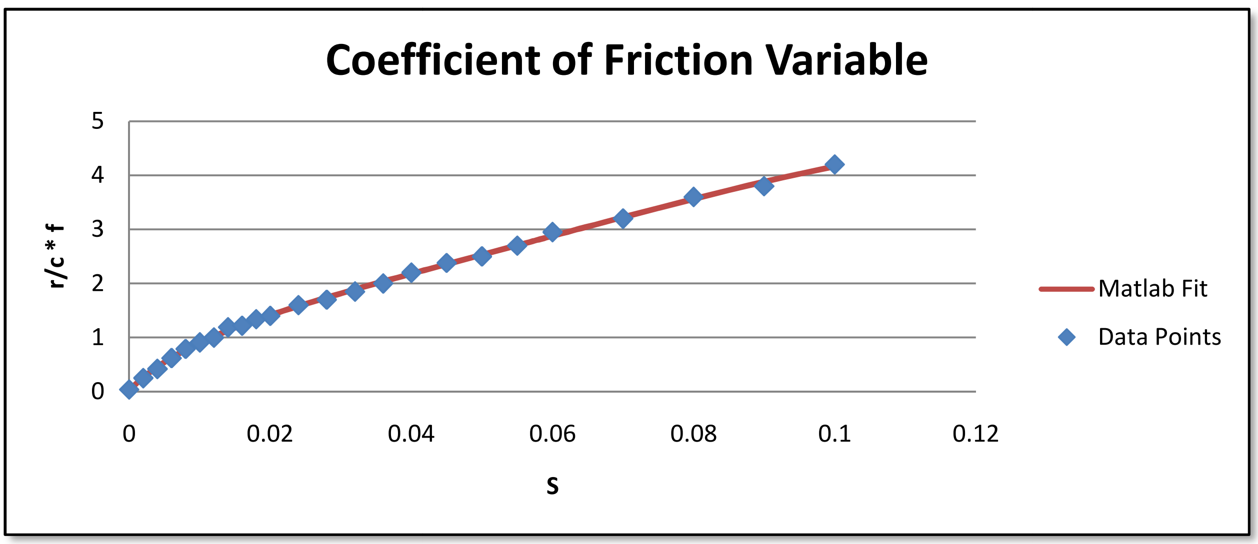
Encyclopedia Britannica, Inc. 1994. 21 Sept. 2008 <http://media-2.web.britannica.com/eb-media/90/4190-004-4DAAB8E9.gif>

Shigley, J. (2008). *Shigley's Mechanical Engineering Design*. 8th ed. New York, NY: McGraw-Hill. p597-648.

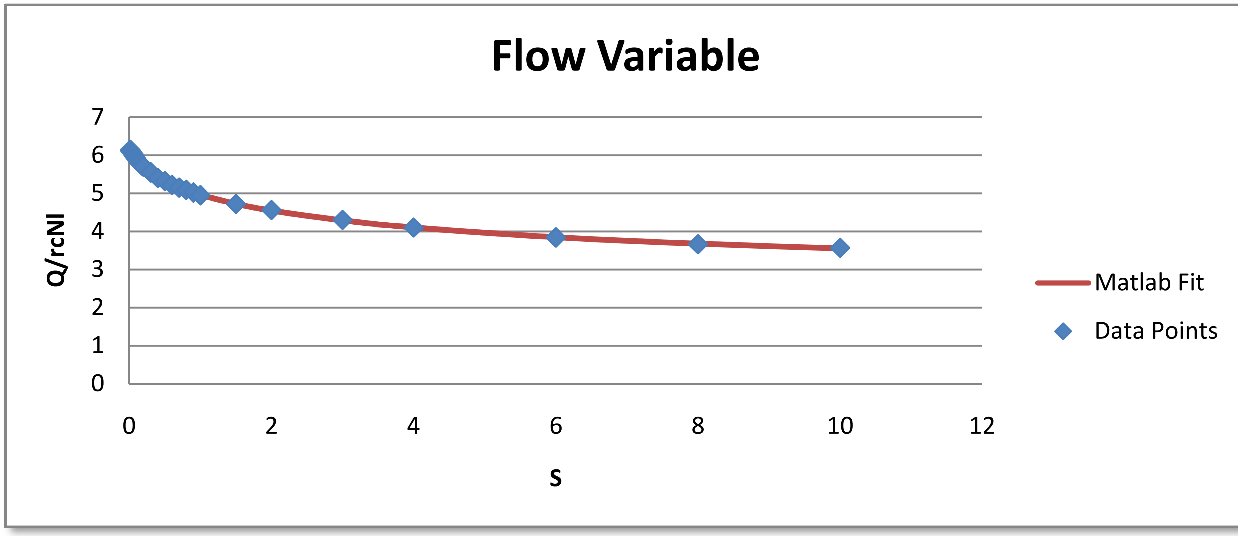
Appendix

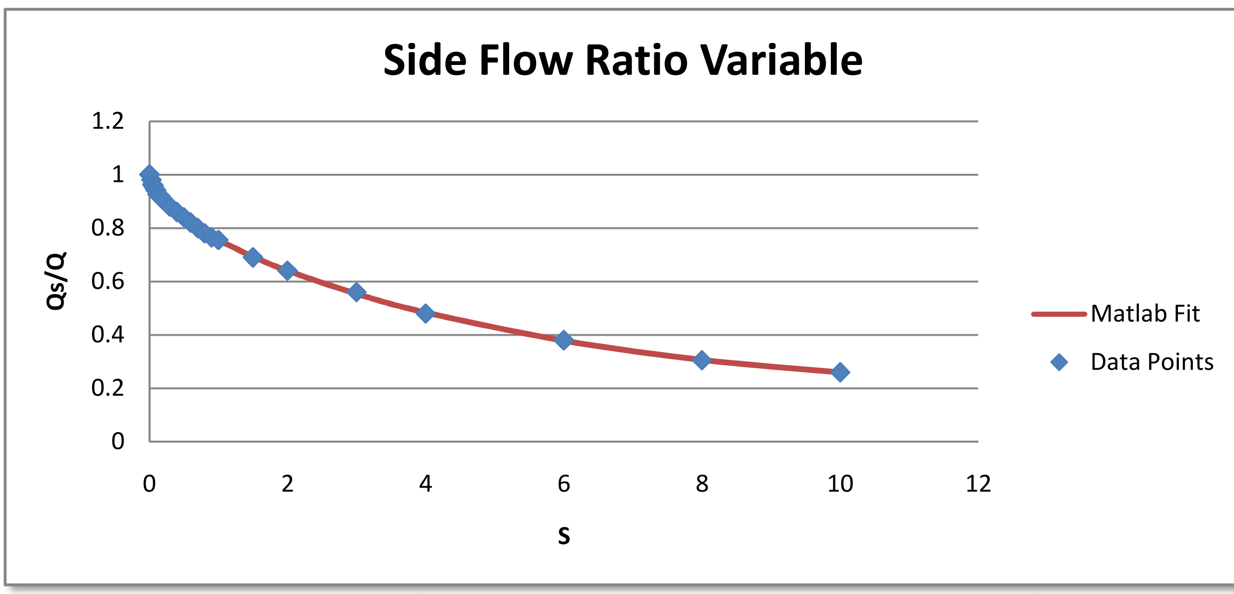


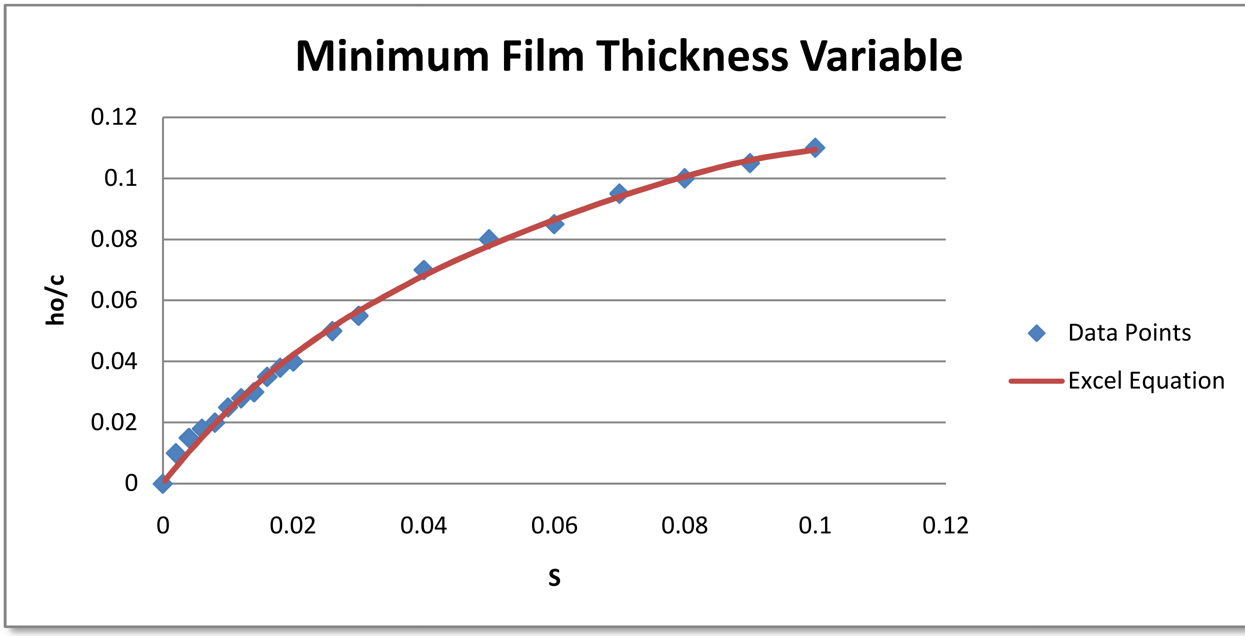
SAE 20 Oil
Absolute Viscosity (μreyn)
7
6
5
4
3
2
1
0
0
50
100
150
200
250
Temperature (F)
Matlab Fit
Data Points



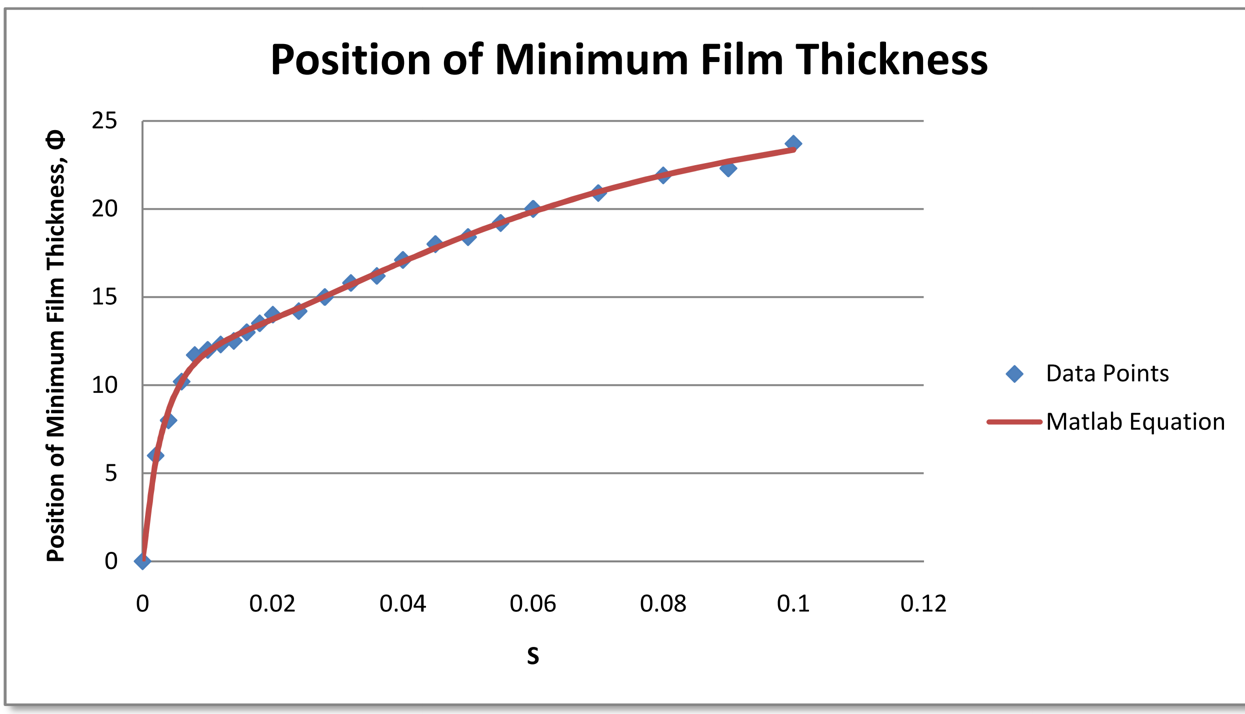
Coefficient of Friction Variable
r/c * f
5
4
3
2
1
0
0
0.02
0.04
0.06
0.08
0.1
0.12
S
Matlab Fit
Data Points

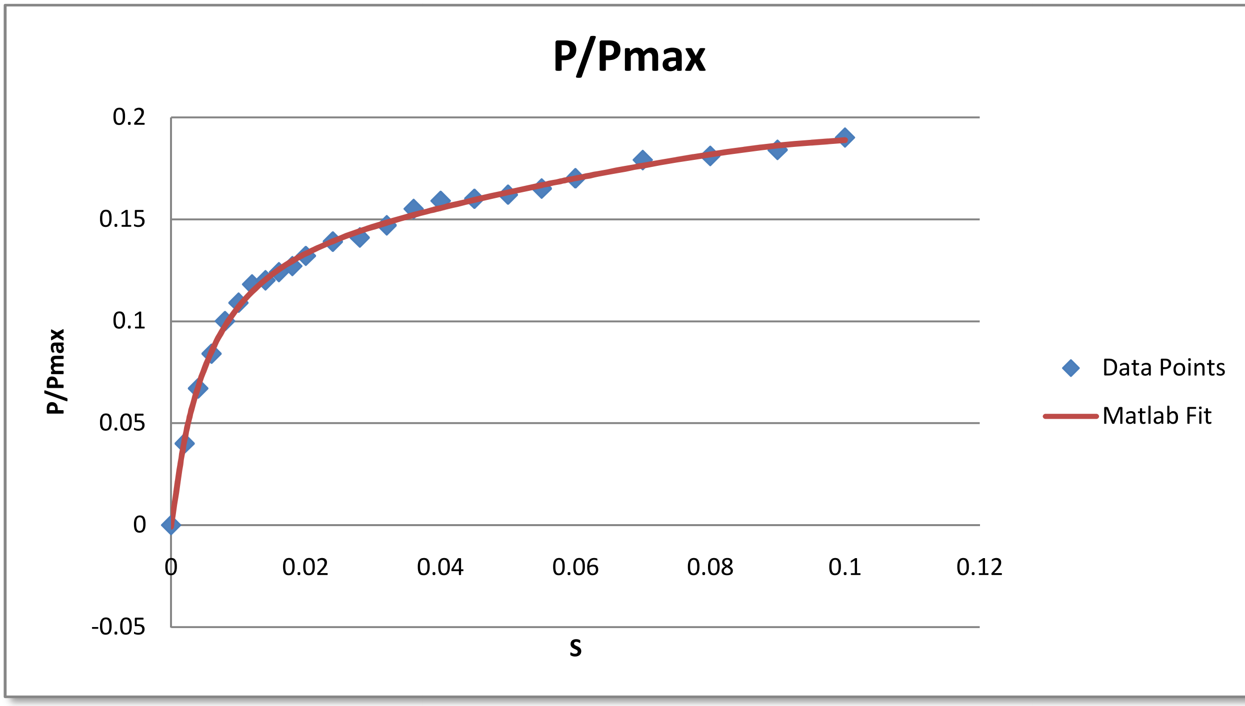

Flow Variable
Q/rcNl
7
6
5
4
3
2
1
0
0
2
4
6
8
10
12
s
Matlab Fit
Data Points


Side Flow Ratio Variable
Qs/Q
1.2
1
0.8
0.6
0.4
0.2
0
0
2
4
6
8
10
12
s
Matlab Fit
Data Points


Minimum Film Thickness Variable
ho/c
0.12
0.1
0.08
0.06
0.04
0.02
0
0
0.02
0.04
0.06
0.08
0.1
0.12
S
Data Points
Excel Equation

—


Position of Minimum Film Thickness
Position of Minimum Film Thickness, Φ
25
20
15
10
5
0
0
0.02
0.04
0.06
0.08
0.1
0.12
S
Data Points
Matlab Equation


P/Pmax
0.2
0.15
0.1
0.05
0
-0.05
P/Pmax
0
0.02
0.04
0.06
0.08
0.1
0.12
S
Data Points
Matlab Fit

Matlab File

```
function JournalBearingDeltaT

i=1;
P=1461.9; %pressure in psi
Ti=125; % initial temp in F

for clearance=0.001:0.0001:0.01
    c(i)=clearance;
    Tguessnew=Ti;
    j=0;

    while j==0
        Tguess=Tguessnew;
        Visc(i)  = 1.312*10^4*exp(-0.08009*Tguess)+32.17*exp(-0.01775*Tguess);
        S(i)     = (4/c(i))^2*Visc(i)*10^-6*5/P;
        ho(i)    = ((-1290.7*S(i)^4)+(333.2*S(i)^3)+(-36.662*S(i)^2)+(2.7187*S(i)))*c(i)*10^6;
        E(i)     = 1-(ho(i)*10^-6)/c(i);
        f(i)     = (0.05845*S(i)+1.103*10^-5)/(S(i)^3-0.2438*S(i)^2+0.024*S(i)+0.0004448);
        flow(i)  = (2.794*S(i)^2+25.24*S(i)+11.14)/(S(i)^2+5.099*S(i)+1.801);
        if S(i)>0.003
            sflow(i) = (0.01724*(log(S(i)))^3+1.141*(log(S(i)))^2-
                                  6.831*log(S(i))+10.63)/(log(S(i))^2-6.474*log(S(i))+14.08);
        else
            sflow(i) = 1;
        end

        delT(i)=(P/9.7*f(i))/((1-0.5*sflow(i))*flow(i));

        Tguessnew=Ti+delT(i)/2;

        if abs(Tguessnew-Tguess)<0.1
           j=1;
        end

        Tguessed(i)=Tguess;
    end
    i=i+1;
end
%c
%delT
wholewheat=[c',Visc',Tguessed',S',E',ho',f',flow',sflow',delT'];

disp('    c         Visc     T avg       S          E         ho          f          flow      side
flow  delT')
disp(wholewheat)

[AX,H1,H2] = plotyy(c,delT,c,ho);
set(get(AX(1),'Ylabel'),'String','Temperature Change (degree F)')
set(get(AX(2),'Ylabel'),'String','Minimum Film Thickness (micro inches)')
xlabel('Clearance (inches)')
```